DeltaRail

VAMPIRE Pro

US DOT Volpe Center

Dynamic Wheel/Rail Benchmark

INTRODUCTION

This problem was proposed by the FRA/DTT Cooperation Team to help analyse differences between several wheel/rail codes using either elastic normal or constraint equations.

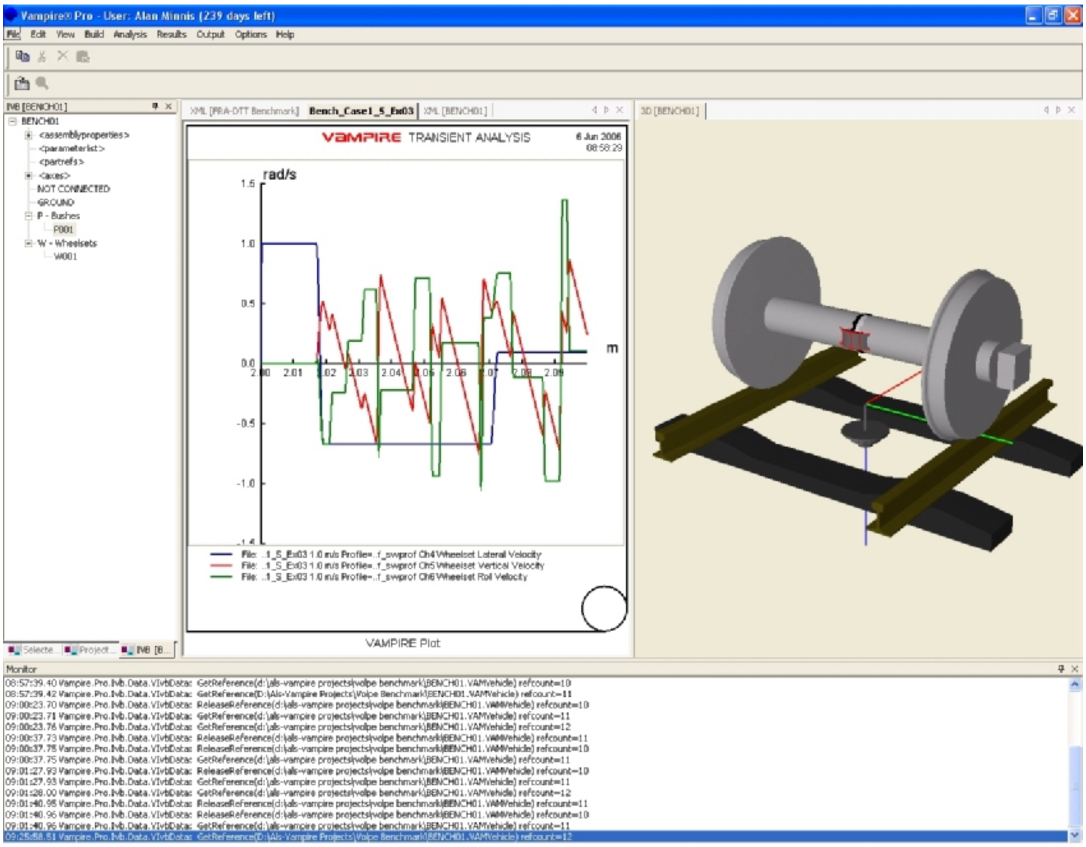
The benchmark comprises a single wheelset on rigid track with zero wheel rail friction. The intent is to analyse normal contact force calculations and the modelling of flange impacts.

DELTARAIL SUBMISSION

For this benchmark exercise DeltaRail Group Limited have undertaken calculations using VAMPIRE Pro, the latest version of VAMPIRE released earlier this year.

Interactive Workspace

VAMPIRE Pro is a fully interactive version of the VAMPIRE package. It allows vehicle models and analysis files to be developed interactively within a workspace environment using a Graphical User Interface (GUI) with data displayed both visually and in tree structures.

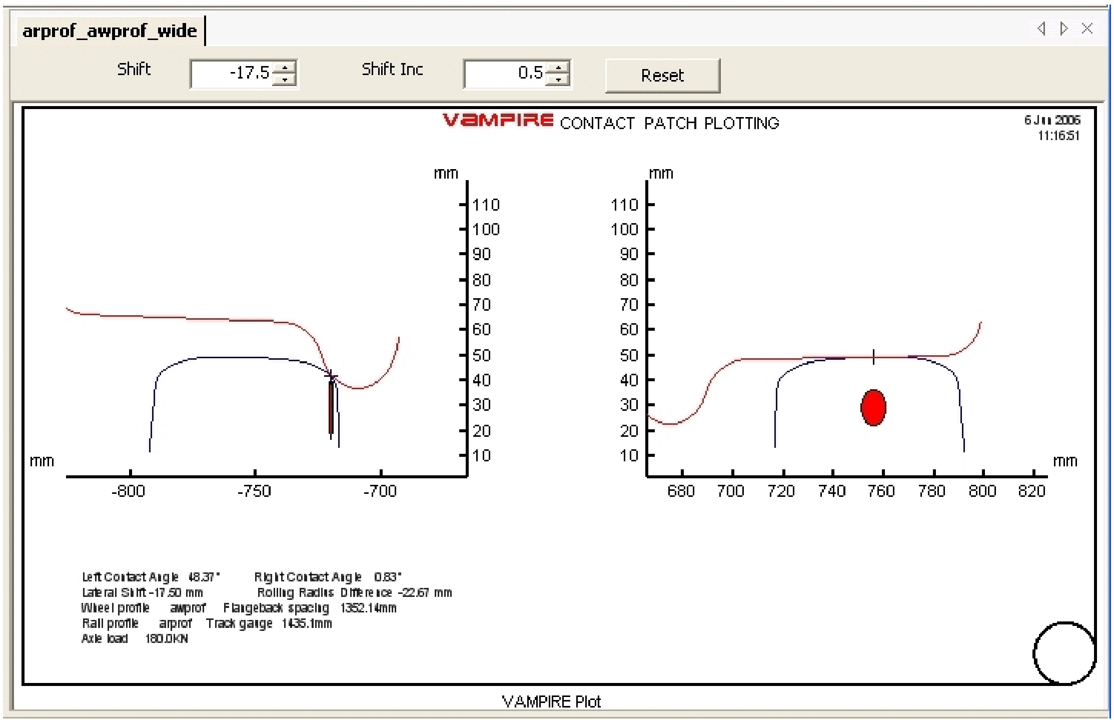


The tree driven structure allows data to be stored and displayed in a clear format making it simple to organise projects and model data. The information relating to projects and models files is stored in xml data files.

The Project tree allows users to keep track of the status of each input file. It automatically updates and indicates where calculations are out of date and need to be re-submitted to use the latest input files.

VAMPIRE Pro Processing Tools

VAMPIRE Pro includes a number of new processing tools allowing users to visualise the contact patch parameters used for each calculation.



The pre and post-processors have also been updated to include common Windows functions including graph tooltips, dynamic zooming and copying of graphs and data to the clipboard for pasting into reports etc.

Every processor now supports task files which allows the user to save the settings of any process. These task files can be used simply to restore graphical settings or they can be converted to template task files and driven from a command process to automate much more complex analyses and data processing tasks from one single command file. This is used extensively to automate standard calculation procedures.

Analysis Programs

A number of enhancements have been made to the analysis programs including improvements to vehicle modelling through use of element names, virtual transducers and flexibility in the ordering and referencing of dynamic elements.

Analysis files now support mathematical functions for combining virtual transducers and creating the desired measurements to be stored in the results files.

Much work has been done on the storage, buffering and interpretation of track data. This work makes simulation results much more robust particularly in severe flanging conditions on tight curves or through S&C.

New to VAMPIRE Pro are Track Parameter and Track Contact files. These allow users to modify the track parameters such as track flexibility and wheel/rail adhesion with respect to distance along the track. The Track Contact file allows users to specify varying contact data with respect to distance along the track.

VAMPIRE Pro also includes a completely revised Kalker table which extends the range of the old table and increases the density of data points where required. The new table now includes 28,800 data points and was derived using the latest CONTACT program held by Vortech Computing.

VAMPIRE PRO NON-LINEAR CREEP LAW

For the benchmark exercise the latest VAMPIRE Pro Non-Linear Creep law was used. This creep law uses a pre-calculated contact data table which describes the contact data parameters with respect to wheelset lateral shift across the track at rail level. The contact data program uses wheel and rail profile data described in the form of Y-Z coordinates. This effectively describes the wheel rail contact as a rigid constraint but the analysis code allows for 'lift off' during periods of 100% wheel unloading. The calculation can identify a single region of two point contact and the effects of this are handled in the non-linear creep law.

The contact data was computed for a wide range of lateral shifts +/-80mm to allow the wheelset to fully climb the rail and simulate derailment where necessary.

During the analysis the non-linear creep law calculates non dimensional creepages at the contact points and uses these to determine the non dimensional creep forces from the Kalker look up table. These are then converted to actual creep forces knowing contact parameters such as wheel rail friction.

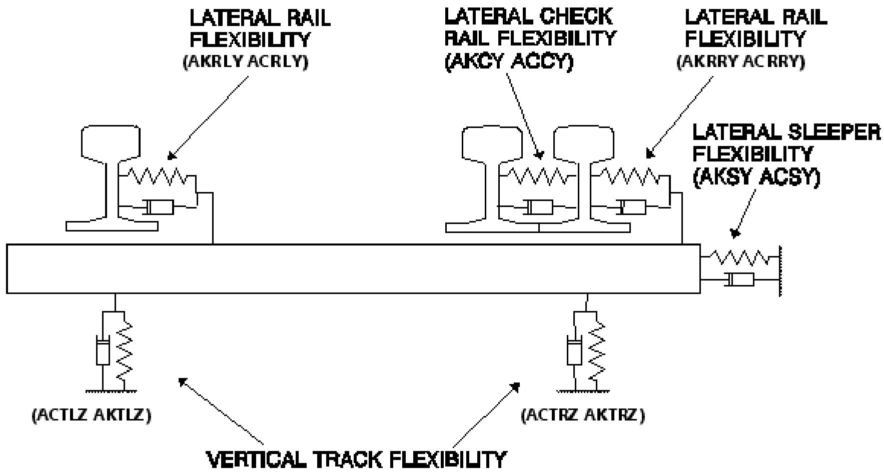
The friction level is therefore inherent in this method of calculation and therefore could not be set to zero, which in any analysis is a extremely unusual condition. However a very low value (0.0001) was achievable in this case without causing any stability problems in the output terms from this analysis. A larger friction level did result in some energy dissipation which was noticeable in the wheelset lateral velocity channels. The results are therefore sensitive to friction levels used and the benchmark did not indicate what level of friction would be acceptable for these benchmark calculations for packages that cannot simply switch off wheel rail friction.

TRACK MODEL

In VAMPIRE the Non-Linear Creep Law requires a track flexibility model as the wheel and rail contact is effectively modelled as a constraint. The track flexibility is used to compute the normal contact force between the wheel and rail. This approach is generally considered accurate when typical track flexibility is considered. The track flexibility terms tend to be the dominating factor when typical track flexibility is compared against the high stiffness contact between a steel wheel and rail.

In this benchmark, however, the definition called for infinitely rigid track which is not achievable in VAMPIRE. The VAMPIRE track model was therefore adjusted to remove all damping terms and to stiffen the track as much as possible to effectively simulate rigid track whilst retaining some flexibility to approximate an elastic contact stiffness between a steel wheel and rail. The result is the VAMPIRE model will only accurately compute an impact force (f) for one specific normal contact, however the impulse response f(t) should be broadly similar thus producing a similar wheelset response.

The VAMPIRE track model is shown below:



VAMPIRE allows linear stiffness and damping terms to be specified between the rail and sleeper and sleeper to ground as shown above. Typical stiffness terms are:

43kN/mm – Lateral rail to sleeper (AKRLY, AKRRY)
37kN/mm – Lateral sleeper to ground (AKSY)
50kN/mm – Vertical stiffness to ground under each rail (AKTLZ, AKTRZ)

The rails and sleepers are considered to be massless degrees of freedom.

The actual stiffness terms used for the benchmark are considerably higher and are declared in the Analysis Settings below.

ANALYSIS SETTINGS

The calculations are controlled by VAMPIRE 'run' files. These define the model to be analysed, the speeds simulated and define the other input files to be used in the simulation. In this benchmark the run file was used to define the track flexibility. In VAMPIRE the non-linear creep law effectively defines a constraint between the wheel and rail profile but allowing for lift off. The program therefore requires some form of track flexibility in order to compute wheel rail forces so the track cannot be set to be infinitely rigid, which would be an extremely unusual condition for any track. The track flexibility model includes independent rail to sleeper flexibilities and sleeper to ground flexibilities. An assessment had to be made in this case as to how stiff the track could be made without causing the calculations to exhibit numerical instability. The simulation results were very sensitive to track flexibility. The optimum solution was to increase the track stiffness to:

100000 kN/mm - Vertical rail to ground
3000 kN/mm - Lateral rail to sleeper
100000 kN/mm - Lateral sleeper to ground

0 MNs/m - Track damping

External vertical loading of the wheelset was achieved by ramping the desired force in over two seconds.

To achieve an initial lateral velocity of the wheelset an external impulse had to be applied to the wheelset lateral degree of freedom. This achieved the desired lateral velocity with reasonable accuracy using an impulse applied over 0.2 milliseconds. This did however produce an acceleration spike at the start of the simulation which was removed from the results. For the case of the Actual coned wheel profiles the impulse also introduced an undesired oscillation in the wheelset response before the first impact.

An integration timestep of 10 microseconds was used for all simulations.

RESULTS

For the wheelset impact simulations (Cases 1-4) an output timestep of 25 microseconds was used whilst for the derailment (Case 5) this was increased to 1 millisecond.

Generally all outputs requested have been supplied. In the case of flange contact channels VAMPIRE only stores one channel of data rather than left and right flange. Normal and tangential forces can be reported on both tread and flange whilst vertical and lateral forces are only reported per wheel in VAMPIRE rather than flange and tread independently.

Potential and kinetic energy relating to specific bodies cannot be directly output from VAMPIRE and results have been derived from individual energy terms. Some results show a small gain in energy at each impact which slowly decays. It is suspected this may relate to the numerical process and the energy transfers occurring over such short time periods.

The impact simulations have been run up to the point where the wheelset returns to the track centre line after first impacting the left rail and then the right rail.